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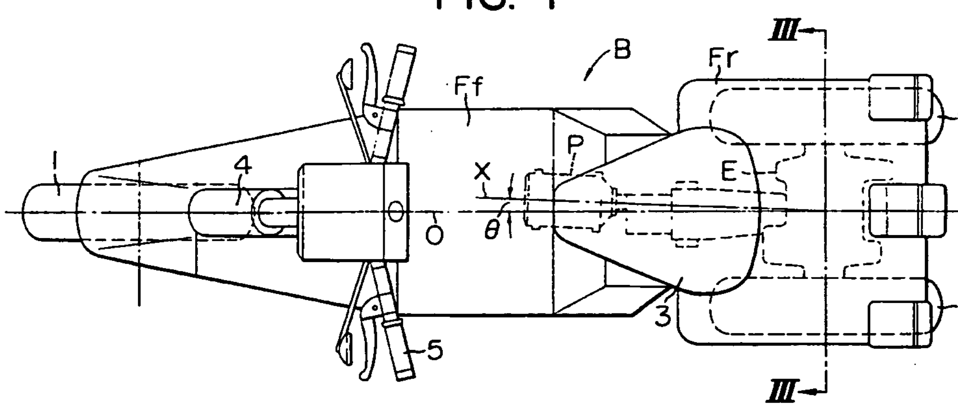
# (54) Three-wheeled vehicles

(57) A unilateral rear-wheel-drive three-wheeled vehicle has a front wheel (1) disposed in the longitudinal plane of symmetry (O) of the vehicle and a pair of rear wheels ($2_1$, $2_2$) disposed symmetrically with respect to the plane (O). A pivot joint (P) interconnecting front and rear frames ($F_f$, $F_r$) of the vehicle has its rotational axis offset from the plane (O) to that side of the vehicle on which the driving rear wheel ($2_1$) is disposed and extending in a direction inclined laterally outwardly from rear to front of the vehicle. Such a pivot arrangement is highly effective to improve the driving stability of the vehicle without involving any structural complication or increase in cost of production, the disposition of the pivot counteracting the tendency for the vehicle to turn to one side under the drive torque of the driven wheel.

FIG. 1

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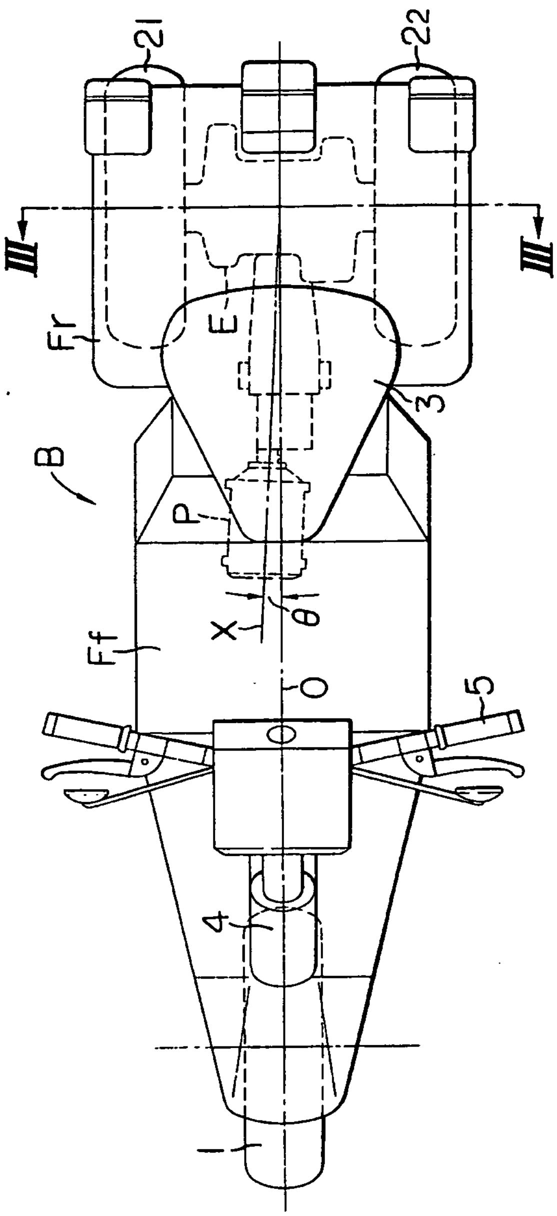



FIG. 1

FIG. 2

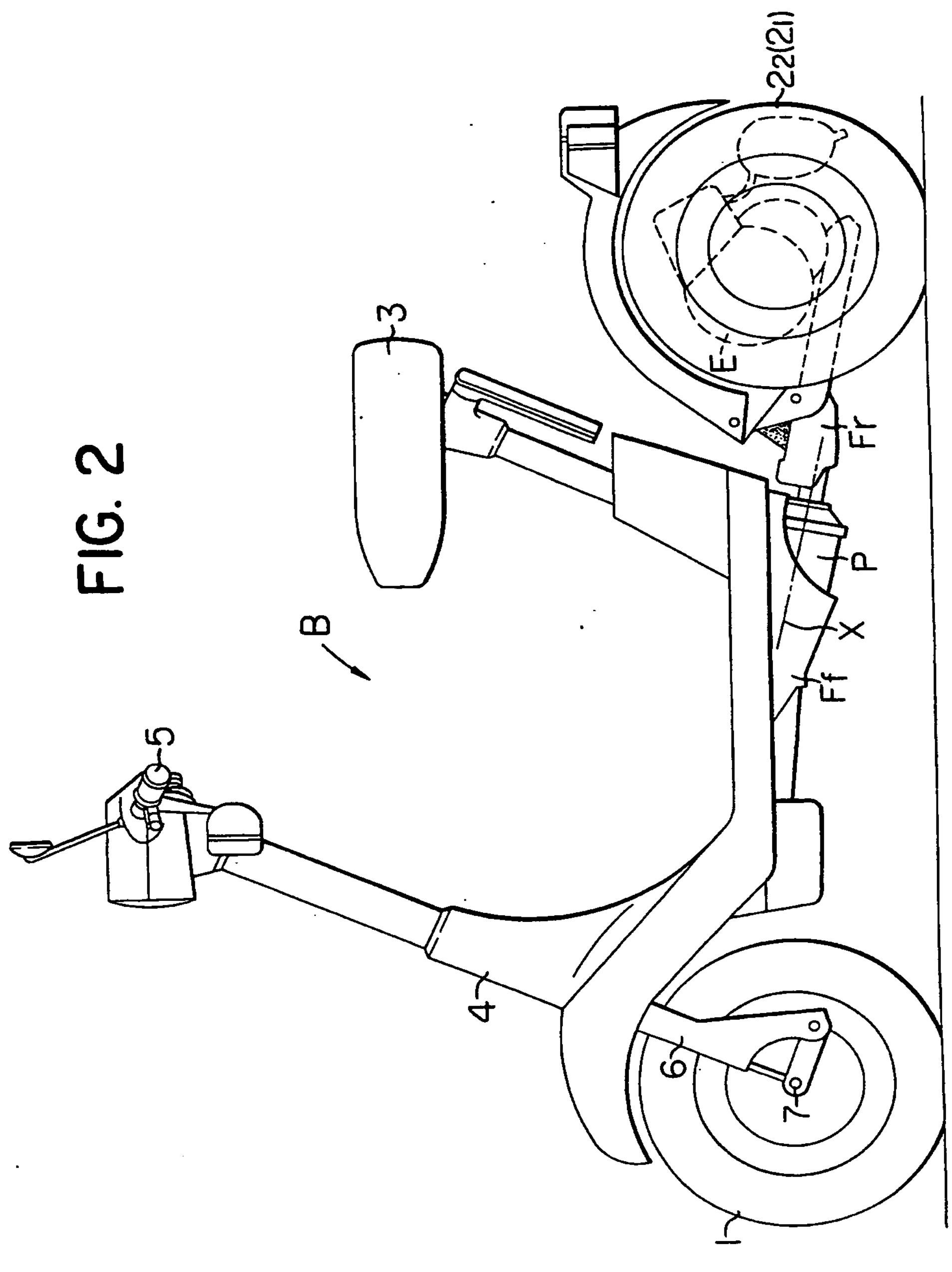


FIG. 3

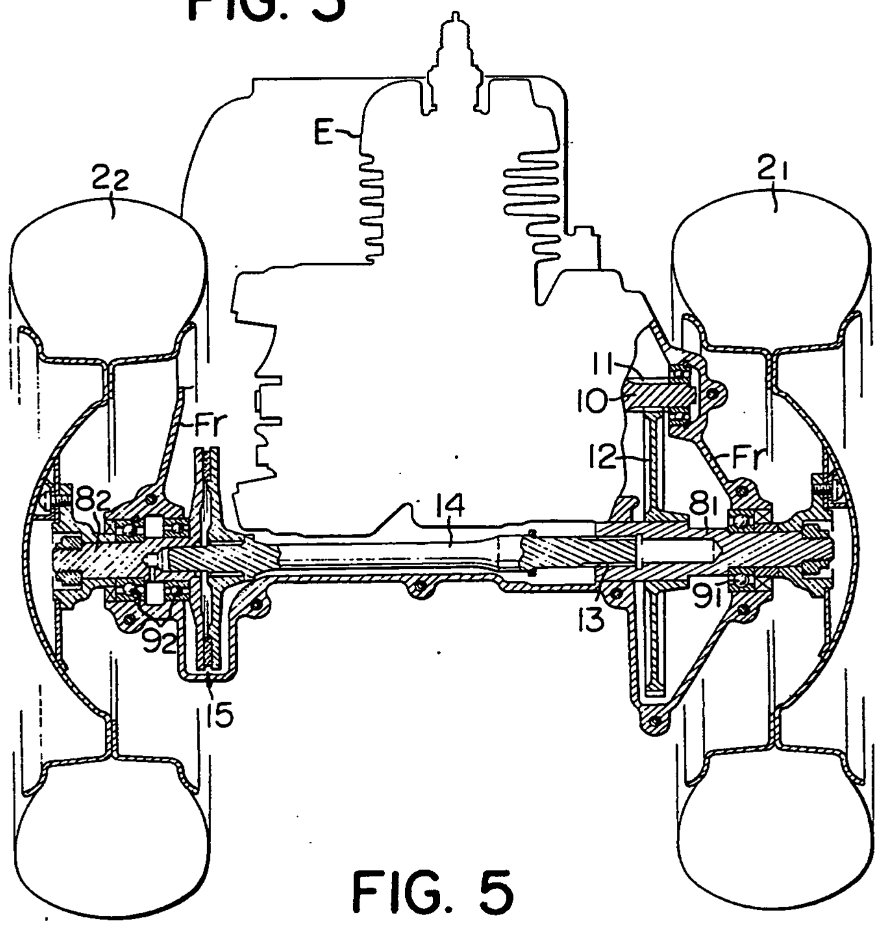
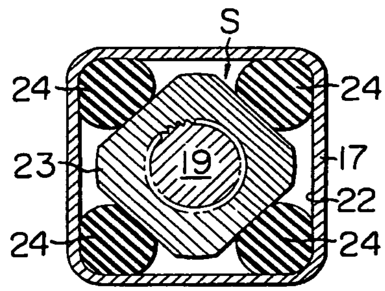



FIG. 5



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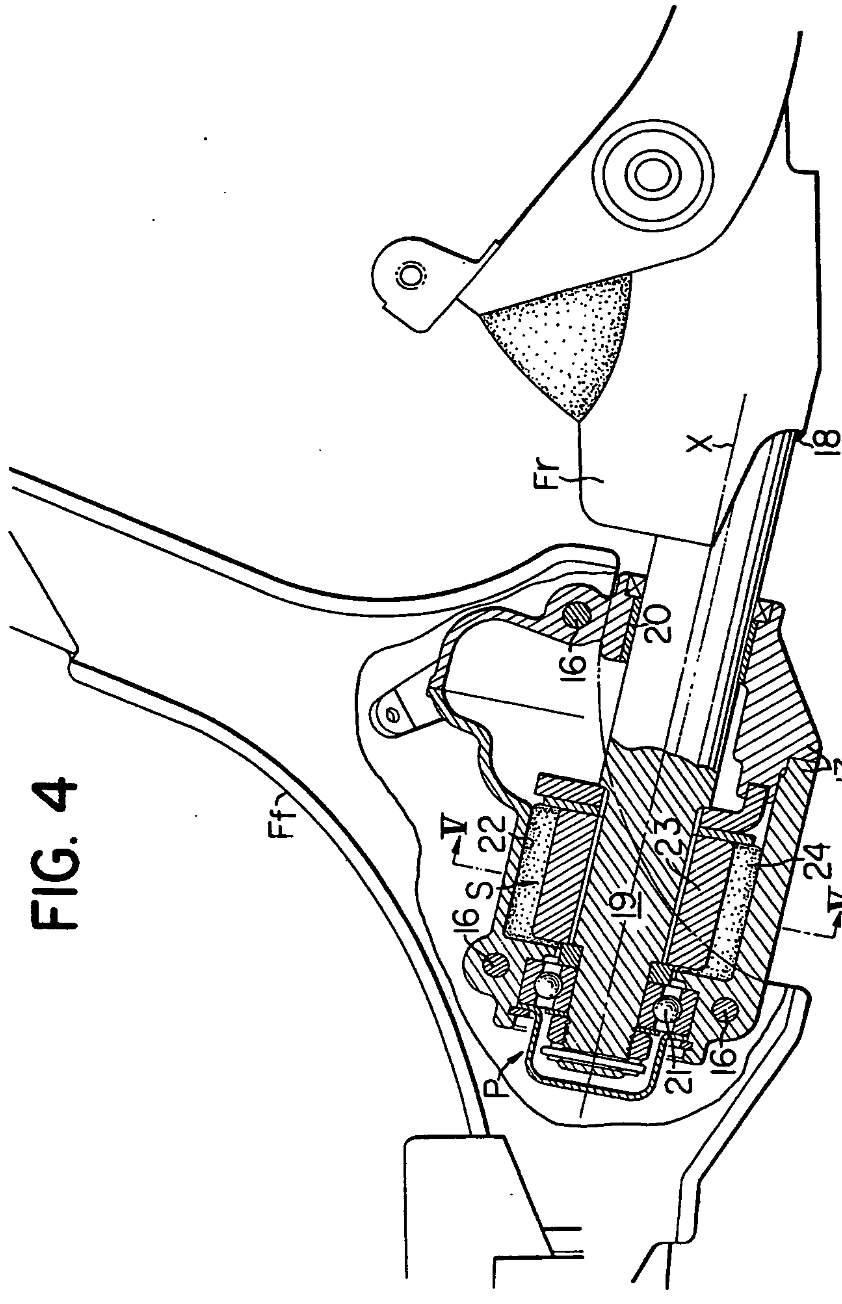



FIG. 4

FIG. 6

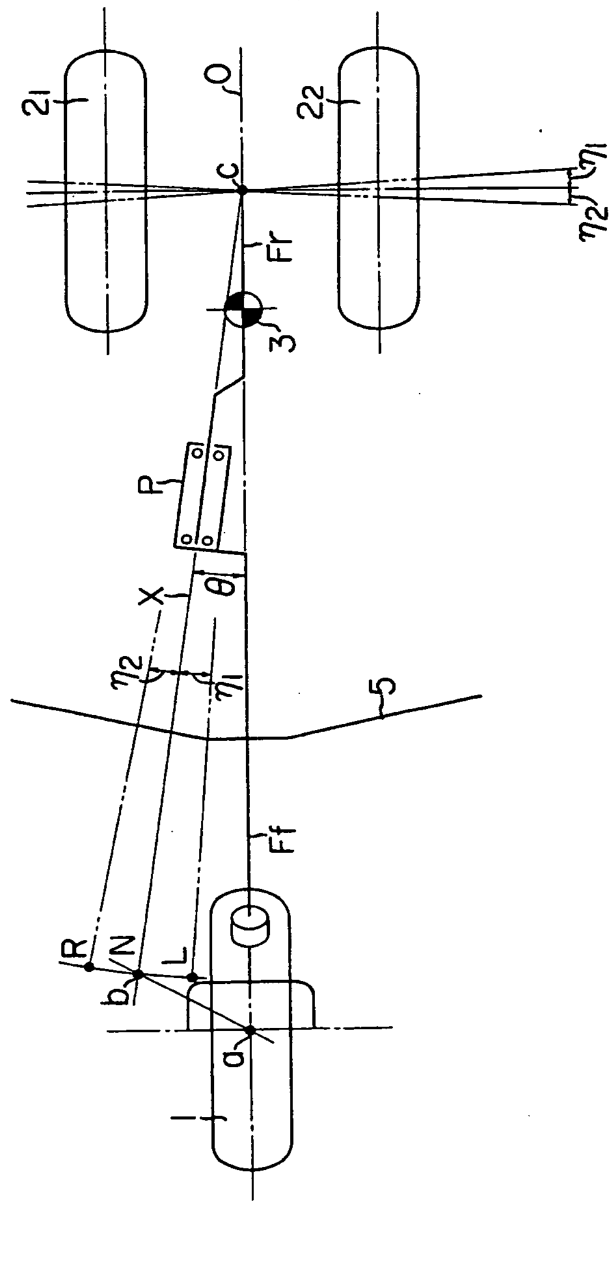


FIG. 7

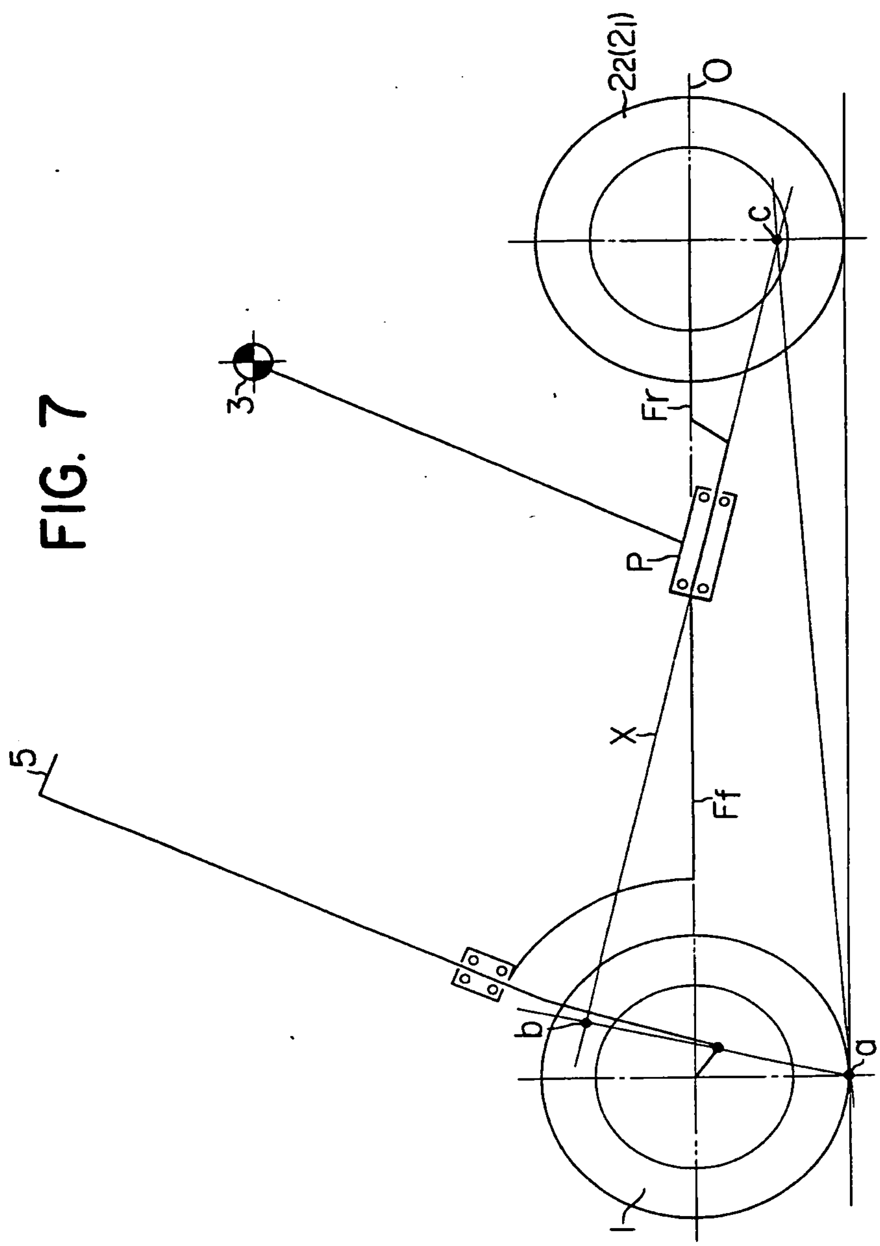
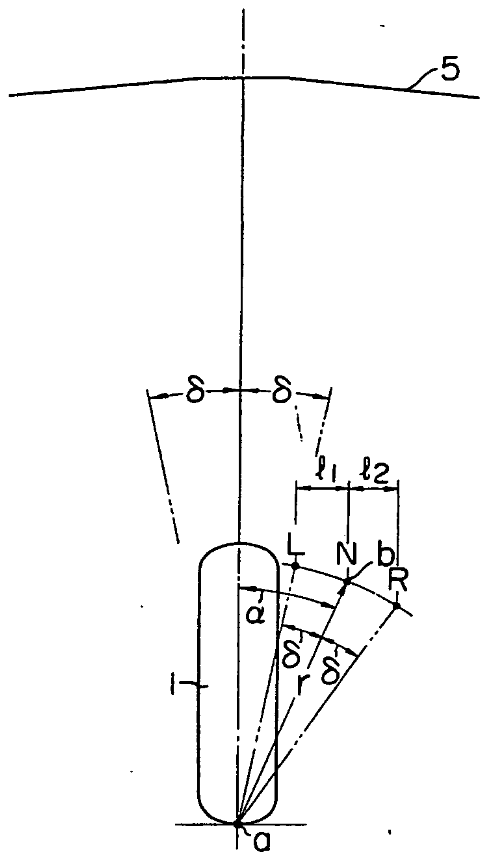


FIG. 8



SPECIFICATION

**Unilateral rear-wheel-drive three-wheeled vehicles**

This invention relates to three-wheeled vehicles of the type comprising a front frame supporting a single front wheel and a rear frame supporting a pair of rear wheels spaced apart on a common transverse axis, the front and rear frames being connected with each other by means of a pivot joint so that the front frame may tilt to one side or the other about the rotational axis of the pivot joint, and a power drive unit, such as an internal combustion engine, operatively connected with one of the rear wheels. Three-wheeled vehicles of this type, having unilateral rear-wheel-drive, generally have the advantages of stuctural simplicity of the power transmission between the drive unit and the rear wheel directly associated therewith, and hence are low cost in production. Conventionally, however, they are disadvantageous in that the transmission of driving power to one only of the two rear wheels tends to give rise to a turning moment which acts in a direction to cause the vehicle to turn to the side opposite the side on which the driving rear wheel is disposed. During straight line running of the vehicle, therefore, the driver is required to hold the steering bars in a position to produce a turning moment that acts in a direction opposite to the afore-said turning moment to counterbalance the latter. Further, the driver's steering effort required to turn the vehicle, for example, to the right must generally be different from that required to turn the vehicle to the left. With vehicles of the type described, therefore, the driver's feel in driving the vehicle has been very unsatisfactory.

According to the present invention there is provided a three-wheeled vehicle comprising a front member and a rear member which are connected with one another for relative pivoting movement about a normally horizontal axis; a single front wheel on the front member located in a plane of symmetry of the vehicle and a pair of rear wheels on the rear member located equidistantly spaced from said plane on a common transverse axis; a prime mover operatively connected to one of the rear wheels with a resultant tendency of this one rear wheel to exert a torque on the front member in direction towards the side on which this one rear wheel is located; and means for at least substantially negating this torque.

In the particular embodiment hereinafter described a three-wheel d v hicle comprising a front frame supporting a singl front whe l and a rear frame supporting a pair of rear wheels spaced apart on a common transverse axis, the front and rear frames b ing interconnected by means of a piv t joint so that the fr nt frame may tilt to one sid r th other about the rotational axis of the pivot joint, and a power drive unit operatively connected with one of the rear wheels; the rear wheels being disposed symmetrically with respect to the longitudinal plane of symmetry of the vehicle, and the pivot joint being arranged so that the rotational axis thereof is generally offset from this plane to that side of the vehicle at which said one rear wheel is disposed and is inclined laterally outwardly from the rear towards the front of the vehicle. By this arrangement, the spatial position of the axis of the pivot joint and its direction are such that the turning moment acting on the vehicle due to the effect of the unilateral rear-wheel-drive is counterbalanced, enabling the vehicle to exhibit a satisfactory propensity to run straight whilst the advantages of simple construction and low production cost are retained.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:–

*Figure 1* is a general plan view of a three-wheeled vehicle;

*Figure 2* is a side view of the vehicle of Fig. 1;

*Figure 3* is a cross-sectional view taken along the line III–III in Fig. 1;

*Figure 4* is a side view, partly in longitudinal cross section and drawn on a larger scale, illustrating the construction of a pivot joint of the vehicle of Figs. 1 to 3;

*Figure 5* is a cross-sectional view taken along the line V–V in Fig. 4 and

*Figures 6, 7 and 8* are, respectively, a schematic plan diagram, side diagram and front diagram of the three-wheeled vehicle, drawn to explain the principles of operation thereof.

Referring first to Figs. 1 and 2, the chassis or body B of the three-wheeled vehicle illustrated includes a front frame $F_f$ which supports a single front wheel 1 and a saddle 3, and a rear frame $F_r$ which supports a pair of rear wheels $2_1$ and $2_2$. The front wheel 1 is disposed in the longitudinal plane of symmetry 0 of the vehicle while the two rear wheels $2_1$ and $2_2$ are disposed symmetrically with respect to the plane of symmetry 0, that is, at locations equidistant from the plane 0, one to one side of the vehicle and the other to the other side.

Formed on the front frame $F_f$ at the front end thereof is a tubular head support 4 in which a front fork 6 is rotatably mounted. Secured to the top end of the front fork 6 is steering handle bar 5. The front whe l 1 is supported at th bottom of the front fork 6 by m ans of a front axl 7.

As seen in Fig. 3, the rear wheels $2_1$ and $2_2$ are fixedly mounted on rear axles $8_1$ and $8_2$, resp ctively, for rotation therewith. The r ar

axles $8_1$ and $8_2$ are rotatably supported by respective brearings $9_1$ and $9_2$, which are provided on opposite sides of the rear frame $F_r$.

In the embodiment illustrated, the right-hand-side rear wheel $2_1$ serves as a driving wheel and, accordingly, a driven gear 12 is fixedly mounted on the right-hand-side rear axle $8_1$. Held in meshing engagement with the driven gear 12 is a drive gear or pinion 11 which is provided on the output shaft 10 of a power drive unit E, such as an internal combustion engine, mounted on the rear frame $F_r$.

Further in the embodiment illustrated, there is provided an intermediate shaft 14 which is spline-connected at one end to the right-hand-side rear axle $8_1$, as indicated at 13 in Fig. 3, and is rotatably received at the other end in the adjacent end of the left-hand-side rear axle $8_2$. The intermediate shaft 14 and rear axle $8_2$ are connected together through the intermediary of a friction differential unit 15, which is itself well known in the art. With this arrangement, it will be noted that part of the driving force of the driving wheel, i.e., the right-hand-side rear wheel $2_1$, is transmitted through the friction differential 15 to the left-hand-side rear wheel $2_2$ to reduce the tendency of the vehicle B to turn to the non-drive side, i.e. in this example to the left side and that, when the vehicle is driven around a curve, the friction differential 15 with its slip action enables the two rear wheels $2_1$ and $2_2$ to roll at speeds different from each other, the rear wheel on the outside of the curve rolling faster than the one on the inside.

The front and rear frames $F_f$ and $F_r$ are interconnected by a pivot joint P the turning axis X of which is generally offset from the longitudinal plane of symmetry 0 of the vehicle B to that side of the vehicle on which the driving rear wheel $2_1$is arranged and extends in a direction inclined laterally outwardly from rear to front of the vehicle at an angle $\theta$ (Fig. 1) to the longitudinal plane of symmetry of the vehicle. Preferably, the pivot axis X is also inclined upwardly from the rear to the front of the vehicle, as seen in Fig. 2.

Referring next to Figs. 4 and 5, the pivot joint P consists of a pivot housing 17 fixed to the front frame $F_f$ by bolts 16 and a pivot shaft 19 fixed to the rear frame $F_r$ by welds 18 and extending into the pivot housing 17. The pivot shaft 19 is rotatably supported adjacent its front and rear ends in the front and rear end walls of the pivot housing 17 by means of a ball bearing 21 and a plain bearing 20, respectively. The pivot shaft 19 and housing 17 thus assembled together have a rotational or pivot axis disposed as above described and as indicated at X in Figs. 1 and 2. Accordingly, the front fram $F_f$ is tiltable about the pivot axis X in relation to the rear frame $F_r$.

In order to resist the tendency of the rear frame $F_r$ to ov r-turn und r the effect of centrifugal force when negotiating a curve, the pivot joint P is provided with a spring device S of the so-called Neidhart type. Specifically, the pivot housing 17 is formed so as to define therein a spring chamber 22 which is substantially square in transverse cross-sectional shape and which chamber accommodates a spring actuator member 23 which is also substantially square in transverse cross-sectional shape and fixedly fitted over the pivot shaft 19. As is clearly shown in Fig. 5, four cylindrical-shaped rubber springs 24 are held one in each of the four corners of the spring chamber 22 in pressure engagement with the respective flat sides of the spring actuator member 23. When the front frame $F_f$ rolls or tilts to one side or the other, causing the pivot housing 17 to turn on the pivot shaft 19 about the axis X, the rubber springs 24 are twisted or compressed obliquely against the respective adjacent flat sides of the spring actuator member 23, so as to exert a torque on the pivot shaft 19 which counteracts the turning moment acting on the rear frame $F_r$ under centrifugal force.

Description will next be made of the principles of operation of the vehicle when driven around a curve, with reference to Figs. 6 and 8.

When the front frame $F_f$ is caused to roll to turn the vehicle to the right or left, it may be supposed that the triangle abc, having an apex a at the point of contact of the front wheel 1 with the ground, another apex b at the intersection of the pivot axis X with the normal line drawn thereto from the point of ground contact a and a third apex c at the intersection of the pivot axis X with the vertical center line of the rear axle assembly $8_1$–$8_2$, is tilted to the right or left about the base side a–c of the triangle. Accordingly, the pivot joint P lying on the oblique side b–c of the triangle is swung to the right or left together with the triangle side b–c to turn the two rear wheels $2_1$ and $2_2$ to the right or left unitarily through the intermediary of the rear frame $F_r$, thereby expediting the turning movement of the vehicle.

In this connection, it is to be noted that the angle of right turn $\eta_2$ of the rear wheels $2_1$ and $2_2$ when the front frame $F_r$ is caused to roll to the right by an angle $\delta$ is more or less different from that $\eta_1$ when the front frame $F_f$ is caused to roll to the left by the same amount of angle $\delta$, as will be explained below.

As described before, the pivot axis X is laid offset from the longitudinal plane of symmetry 0 of the vehicle B to that side thereof on which the driving r ar wh l $2_1$ is disposed and extends in a directi n inclined forwardly away from the plane f symmetry 0 at an angle $\theta$. B cause of this, th triangle abc described ab v is held in a position tilted, in

the embodim nt shown, to the right at an angle $\alpha$ to the vertical with the front frame $F_f$ assuming its neutral position of zero angle of rolling with the front wheel 1 standing upright, as illustrated in Fig. 8. Reference character N indicates the spatial position of the apex point b of triangle abc in the frame state described. As the front frame $F_f$ is tilted to the left or right by a definite angle $\delta$, the apex point b is moved arcuately about point a to a position L or R, respectively.

The horizontal distance l1 between the positions N and L and that l2 between N and R are compared below. For convenience in calculation, the pivot axis X is assumed to be horizontal. As will be readily understood, the effects of the spatial arrangement of the pivot axis X are principally the same in nature irrespective of whether the axis is arranged horizontal or inclined upwardly from rear to front though they vary in absolute value with the direction of the axis.

$$l1 = 2r.\cos\frac{\alpha}{2} . \cos(\delta - \frac{\alpha}{2})$$

$$l2 = 2r.\cos(\delta + \frac{\alpha}{2}) . \cos\frac{\alpha}{2}$$

$$l1 - l2 = 2r.\sin\alpha . \sin\delta > 0$$

where

$$|\delta| < \frac{\pi}{2}$$

and

$$0 < \alpha < \frac{\pi}{2}. \text{ Hence } l1 > l2$$

Further, since the horizontal distance of movement of the apex point b and the angle of turn of rear wheels $2_1$ and $2_2$ are proportional to each other, the angles of turn $\eta_1$ and $\eta_2$ of rear frame $F_r$ or wheels $2_1$, and $2_2$, corresponding to the respective horizontal displacements l1 and l2 of apex point b are in the following relation:

$$\eta_1 > \eta_2$$

It follows that, as for the work done for turning the vehicle, the amount of work done for leftward tilt of the front frame $F_f$ must be larger than that for rightward tilt of the same angle. In oth r words, the input r quired for turning th r ar wheels $2_1$ and $2_2$ t th right is generally lighter than that for their turning to the left. This means that steering th vehicle to the right generally requires less effort on the part of the driv r than ste ring to the left. Du to this characteristic, the vehicl during travel is at all times subject to a definite amount of turning moment, tending to turn to the right.

On the other hand, in cases where, as in the illustrated example, the vehicle is driven by an engine E connected solely with the right-hand side rear wheel $2_1$, the vehicle body B undergoes a leftward turning moment on account of the unilateral rear drive which is counterbalanced by the rightward turning moment described above, ensuring the propensity of the vehicle to run straight. In practical applications, it has been found that, by selecting an angle of lateral inclination $\theta$ of pivot axis in a range of from 1° to 5°, as much as 70% to 90% of the turning moment acting on the vehicle due to unilateral rear drive is effectively counterbalanced so that the vehicle can be driven with quite a normal steering feel.

To summarize, according to the present proposals, the spatial position of the axis of the pivot joint and its direction are so specified that the turning moment acting on the vehicle due to unilateral rear-drive is effectively counterbalanced, enabling the vehicle to exhibit a satisfactory propensity to run straight. Accordingly, the driving stability of the vehicle is materially improved, any tendency of the steering handle bars to turn to the right or left during straight travel or any difference between the driver's steering feel for turning to the right and that for turning to the left being eliminated. Consequently, as with the case of three-wheeled vehicles of bilateral rear-drive type, use can be made of a wheel arrangement including a front wheel arranged in the longitudinal plane of symmetry of the vehicle and two rear wheels arranged on a common transverse axis symmetrically with respect to the vehicle plane so that the riding comfort and controllability of the vehicle are highly improved while ensuring the structural simplicity and low cost production features characteristic of unilateral rear-drive type three-wheeled vehicles.

## CLAIMS

1. A three-wheeled vehicle comprising a front member and a rear member which are connected with one another for relative pivoting movement about a normally horizontal axis; a single front wheel on the front member located in a plane of symmetry of the vehicle and a pair of rear wheels on the rear member located equidistantly spaced from said plane on a common transverse axis; a prime mover operatively connected to one of the rear wheels with a resultant tendency of this one rear wh el to exert a torque on the front member in direction towards the side on which this n rear wheel is located; and means f r at least substantially negating this

torque.

2. A thr e-whe led v hicl comprising a front frame supporting a single front wheel and a rear frame supporting a pair of rear wheels spaced apart on a common transverse axis, the front and rear frames being interconnected by means of a pivot joint so that the front frame may tilt to one side or the other about the rotational axis of the pivot joint, and a power drive unit operatively connected with one of the rear wheels; the rear wheels being disposed symmetrically with respect to the longitudinal plane of symmetry of the vehicle, and the pivot joint being arranged so that the rotational axis thereof is generally offset from this plane to that side of the vehicle at which said one rear wheel is disposed and is inclined laterally outwardly from the rear towards the front of the vehicle.

3. A three-wheeled vehicle as claimed in claim 2, wherein the front wheel is arranged in the longitudinal plane of symmetry of the vehicle.

4. A three-wheeled vehicle as claimed in claim 2 or 3, wherein the pivot joint comprises a pivot housing fixed to the front frame and a pivot shaft fixed to the rear frame and extending into the pivot housing, the pivot shaft being rotatably supported adjacent respective front and rear ends thereof in front and rear end walls of the pivot housing by a plain bearing and a ball bearing, respectively.

5. A three-wheeled vehicle as claimed in claim 4, wherein the pivot joint comprises a spring chamber defined in the pivot housing and substantially square in transverse cross section, a spring actuator member disposed in the spring chamber in fixed relation to the pivot shaft and also substantially square in transverse cross section, and four cylindrical rubber springs each held in one of the four corners of the spring chamber in pressure engagement with respective flat sides of the spring actuator member.

6. A three-wheeled vehicle as claimed in any one of claims 2 to 5, wherein the rear wheels are connected with each other by means of a friction differential unit frictionally interconnecting the rear wheels for unitary rotation during straight travel of the vehicle and allowing the rear wheels to roll at speeds different from each other during vehicle travel around a curve.

7. A three-wheeled vehicle substantially as hereinbefore described with reference to the accompanying drawings.

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